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(54) Hydropneumatic suspension for motor vehicles

(57) In a hydropneumatic suspension system for motor vehicles at least two telescopic spring strut cylinders (1) are arranged in the region of the vehicle wheels between the vehicle structure and the axle, and each cylinder is connected through a pressure fluid pipe (16) to a pressure accumulator (7) and is divided into two working chambers (4) and (5) by a damping piston (3) secured on a piston rod (2). In order to achieve an additional influence on the damping force through the pressure fluid pipe (16) and at the same time maintain a positive coupling relationship under all operating conditions, in particular on rapid outward movement of the piston rod (2) (extension stroke), the cross-sectional area for flow in the pressure fluid pipe is influenced by a damping element (8) and a valve (9) is arranged in a bypass (17) in parallel to the damping element. The valve comprises a valve closure surface which is engageable with a seating (15) which is exposed to the pressure of the accumulator (7). The valve closure surface is arranged to be displaced off the valve seating (15) so as to open the bypass wh n the pressure in the working chamber (4) falls below a predetermined value. The damping element (8) and valve (9) can be combined in a single component (Fig. 6).

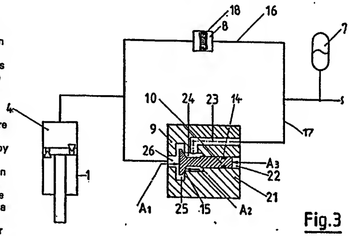

Fig.3

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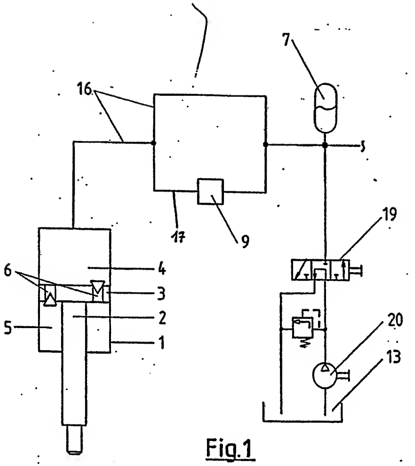

Fig.1

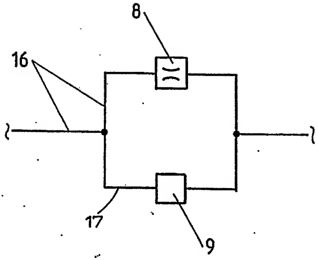

Fig.1a

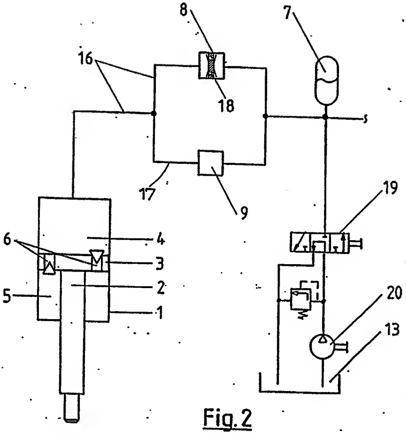

Fig. 2

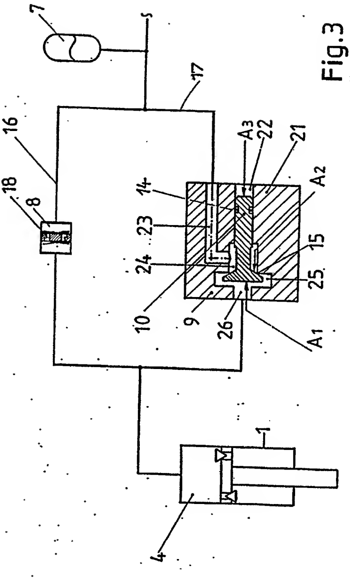

Fig.3

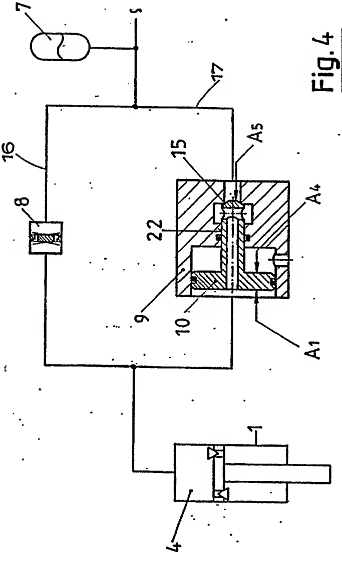

Fig. 4

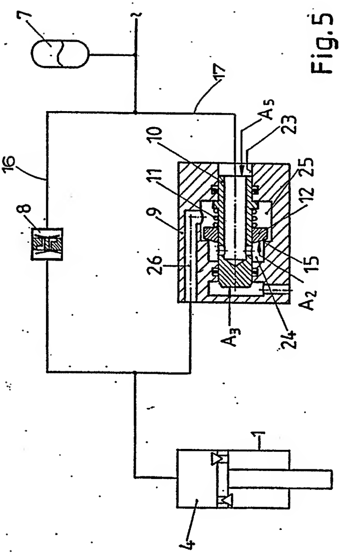

Fig.5

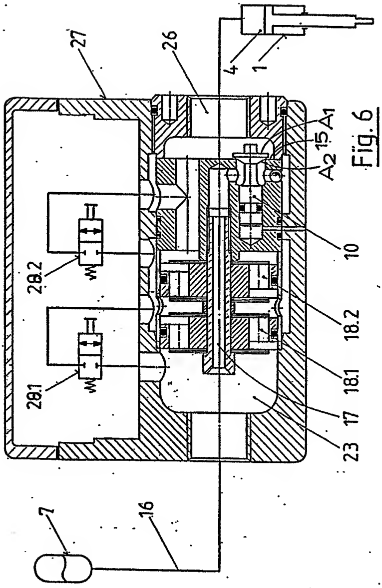

Fig. 6

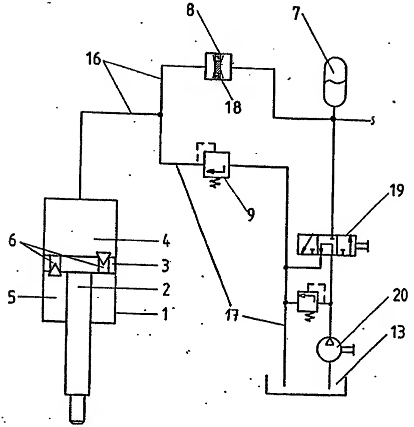

Fig.7

SPECIFICATION

Hydropneumatic suspension for motor vehicles

The invention relates to a hydropneumatic suspension system for motor vehicles of the kind which comprises at least two telescopic spring struts arranged in the region of the vehicle wheels between the vehicle structure and the axle, each telescopic strut being connected to a pressure accumulator and/or reservoir through a fluid pressure connection and the cylinder of each telescopic spring strut being divided into two working chambers by a damping piston secured to a piston rod. Such a hydropneumatic suspension system will hereinafter be referred to as of the kind set forth Damping devices for hydropneumatic suspension systems of the kind set forth are known (e.g. DE-AS 1575191, DE-OS 2322997, DE-OS 3111410), in which between each respective spring cylinder and a pressure accumulator a damping element is provided in the connecting pipe. This damping element serves to influence the damping force. In such systems, on inward movement of the piston rod (the contraction stroke) fluid is forcibly pumped through the damping element in the connecting pipe and to the accumulator. When the piston rod moves outwards (the extension stroke) the fluid flows, driven by the drop in pressure between the accumulator and the working chamber of the strut cylinder, through the damping element and back to the cylinder. When the velocity of outward movement of the piston exceeds the amount by which, corresponding to the designed force-velocity characteristic of the damping element, the fall in pressure at the damping element corresponds to the momentary system pressure in the accumulator, the telescopic spring cylinder loses its positive coupling relationship. This results in a negative pressure in the working chamber, leading to gas being forced from the damping fluid. The resulting formation of bubbles in the working cylinder leads to major upsets in the functioning of the damping system.

It is an aim of the invention so to construct a hydropneumatic suspension system of the kind set forth in which the telescopic suspension cylinder is in communication with a pressure accumulator through a fluid pressure connection, in such a way that an additional influence on the damping force is achieved through the fluid pressure connection, but where a positive coupling relationship remains present under all operating conditions, in particular on rapid extension of the piston rod (the extension stroke).

According to the invention there is provided a hydropneumatic suspension system of the kind set forth in which the cross-sectional area for flow in the fluid pressur connection is influenced by a damping element and a valve is arranged in a bypass in parallel with the damping element, the valve comprising a valve closure surface which is engageable with a valve seating and which is arranged to be displaced off the valve seating so as to open the bypass when the pressure in one of the two working chambers falls below a predetermined value.

An advantage of the system in accordance with the invention is that the positive coupling of the telescopic strut cylinder is maintained under all operating conditions as in particular on rapid extension of the piston rod the flow of the damping fluid does not break up, since in this situation the bypass between the source and the cylinder opens so that negative pressure in the working chamber of the telescopic strut cylinder is prevented.

In order to achieve a further control of the damping force with the damping valves in the telescopic strut cylinder connected in series, the damping element may comprise a part of the pressure fluid connection which has a restricted cross-sectional area that acts as a throttle or it may comprise a valve which incorporates spring-loaded throttle bores.

In another embodiment of the invention, the damping element may comprise a variably alterable damping device.

In one preferred embodiment of the invention the valve closure surface is formed on an axially displaceable control element of the valve which has at least one surface exposed to the pressure in one of the working chambers and at least one other surface exposed to the pressure of the accumulator. In such an arrangement a predetermined opening point for the bypass can be chosen by shaping the individual surfaces with respect to one another having regard to the relationship of the respective pressures on the corresponding surfaces.

In another embodiment, the valve closure surface is formed on a valve closure member connected to an axially displaceable control element which has at least one surface exposed to the pressure of the accumulator.

The valve control element may have a surface exposed to atmosphere so as to support the surfaces exposed to the pressure of the accumulator and the pressure of the working chamber.

The valve closure surface may be biased by a spring into a closed position in which it engages with the valve seating.

In a preferred embodiment of the invention the damping element and the valve may be incorporated within a comm n component.

Some preferred embodiments of the invention will now be described, by way of example only, with r fer nc to th accompanying drawings in which:-

Figure 1 is a diagrammatic illustration of a hydropneumatic susp nsion system in which a

bypass is provided in the connecting pipe between a telescopic strut cylinder and a pressure accumulator;

Figure 2 is a diagrammatic illustration similar to Figure 1, but with a damping element provided in the connecting pipe between the telescopic strut cylinder and the accumulator and a valve provided in the bypass;

Figure 3 shows the valve in the bypass in section;

Figure 4 shows an alternative form of valve provided in the bypass;

Figure 5 shows another form of the valve in the bypass in cross section;

Figure 6 shows an adjustable damping element in the connecting pipe between a telescopic strut cylinder and a pressure accumulator, and a valve in an associated bypass, both of which are incorporated within a common component; and

Figure 7 is a diagrammatic illustration showing the valve employed in a height-regulating installation.

Figure 1 shows a telescopic suspension strut cylinder 1 and a pressure reservoir or accumulator 7 of a hydropneumatic suspension system for a motor vehicle and which are connected together through a pressure fluid pipe 16. A valve 9 is arranged in a bypass 17 in parallel with the pipe 16. The system includes a height regulator 19, a pump 20 and a reservoir 13 and can act as a height-regulating or levelling installation. The telescopic strut 1 is in the form of a single tube vibration damper, the cylinder of which is divided into two working chambers 4 and 5 by a damping piston 3 on a piston rod 2, and passages 6 are provided in the piston 3 to generate a damping force through appropriate valves.

Part of the pipe 16 between the pressure accumulator 7 and the cylinder 1 has a restricted cross- sectional area which acts as a throttle thereby constituting a damping element. Alternatively, as shown in Figure 1a, the damping element may comprise a part component 8 provided in the pipe 16 and which has a restricted cross-sectional area corresponding to a throttle. A valve 9 is arranged in a bypass 17 of the pipe 16 in parallel with the damping element 8. Some different forms of the valve 9 are illustrated and described in detail with reference to Figures 3 to 6.

Figure 2 shows a system similar to Figure 1 but with the difference that the damping element 8 provided in the pipe 16 has spring-loaded throttling bores 18 for damping the flow of fluid. Oth rwis this embodiment corresponds to the hydropneumatic suspension system of Figure 1.

Figure 3 shows a valve 9 in section which is arranged in a bypass of the pressure fluid pipe 16 extending between the pressure accumulator 7 and the telescopic spring strut cylinder 1. The valve 9 is provided with a control element or slide 10 which is axially slidably received in a bore 22 in the valve housing 21. The control element has a control surface A1 exposed to the pressure in the working chamber, a valve closure surface A2 exposed to the pressure of the accumulator 7 and a surface A3 exposed to atmospheric pressure. The surfaces A1, A2, A3 exposed to pressure in this way are of such dimensions that the control element 10 is axially displaced as soon as the pressure in the cylinder 1 falls below a predetermined value in relation to the pressure in the accumulator 7, so that the bypass connection between the accumulator 7 and the working chamber 4 of the cylinder 1 is opened.

In this arrangement the opening pressure is defined as:

P Cylinder = P Accumulator × A2/A1
with the restriction that A2 = A1—A3.

As soon as the pressure in the chamber 4 falls below the pressure in the accumulator 7 by the factor A1/A2 the valve closure surface A2 of the control element 10 is displaced off its valve seating 15, providing a path for flow between the passage 23, the space 24, past the valve seating 15 to the space 25 and the passage 26. A sealing element 14 serves to seal the control element 10 with respect to atmosphere.

The relationship between the areas A1 and A2 is such that a negative pressure in the chamber 4 of the cylinder 1 is avoided, even taking into account the friction of the sealing element 14.

Figure 4 shows a modified valve 9 having a control element 10 which is again arranged to slide axially in a bore 22, and here the pressure in the accumulator 7 and the pressure in the working chamber 4 of the cylinder 1 act on opposed surfaces A5 and A1 of the control element. The surface Al is exposed to the pressure in the chamber 4, the valve closure surface A5 to the pressure in the accumulator 7 and a surface A4 to atmospheric pressure. In this arrangement the control element 10 is axially displaced when the pressure in the cylinder falls below an opening pressure defined as:

P Cylinder = P Accumulator × A5/A1,
with the limitation that A5 = A1-A4.

Figure 5 shows a further variant of the valve 9 in which a valve closure surface A2 on a valv closure member 12 is biased into engagement with a valve seating 15 by a spring 11 through which the closure member is c nnect d to the control element 10.

The valve closure surface A2 is exposed to the pressure in the accumulator 7, an end surface A3 of the control element is expos d to atmospheric pressure and an opposite end

surface A5 of the control element is also exposed to the pressure in the accumulator. The arrangement of the surfaces A2, A3, A5 is such that the valve closure surface A2 of the valve closure member 12 is displaced off the valve seating 15 when the pressure in the working chamber 4 of the cylinder falls below a predetermined opening pressure defined as:

P Cylinder = P Accumulator × (A2-A5)/ A2.

When the valve opens the damping fluid flows through an inlet passage 23 and an axial passage in the valve control member 10 into a space 24 and past the valve seating 15 into a space 25, and from there through another passage 26 to the working chamber 4 of the suspension cylinder 1. In this embodiment there is a minimal flow of leakage fluid past the valve closure member 12, resulting in friction-free and therefore hysteresis-free opening and closing behaviour.

Figure 6 shows a common component 27 which incorporates both a damping element 8 and a valve 9 in a bypass 17. The component 27 is disposed in a pipe 16 which connects the accumulator 7 to the suspension cylinder 1. An inlet passage 23 is arranged on the accumulator side and an outlet passage 26 on the working chamber side. The bypass 17 is closed when a valve closure surface A2 on a control element or slide 10 is in engagement with a valve seating 15 and the damping fluid flows between the passages 23 and 26 through the valves 28.1 and 28.2 and/or through throttle bores 18.1 and 18.2 However when the pressure in the working chamber 4 of the cylinder 1 falls below the predetermined value:

P Cyl = P Accumulator × A2/A1

the slide 10 is displaced axially and opens the bypass connection between the passages 23 and 26.

Figure 7 illustrates the diagrammatic layout of a hydropneumatic suspension system similar to Figure 1, but in which the telescopic suspension strut cylinder 1 has its working chamber 4 connected on the one hand through the pipe 16 and the damping element 8 to the pressure accumulator 7, and on the other hand through the valve 9 in a bypass 17 to a reservoir 13. When the pressure in the working chamber 4 falls below the pressure in the accumulator 7 the valve 9 opens and the amount of fluid which is accordingly required in the chamber 4 can flow direct from the reservoir 13. Apart from this the valve 9 corresponds in principle (apart from the surface exp sed to the pressure in the accumulator) to the examples illustrated in Figures 3 to 5.

CLAIMS

1. A hydropneumatic suspension system for motor vehicles comprising at least two telescopic spring struts arranged in the region of the vehicle wheels between the vehicle structure and the axle, each strut being connected through a pressure fluid connection to a pressure accumulator and/or reservoir and the cylinder of each strut being divided into two working chambers by a damping piston secured to a piston rod, in which the cross sectional area for flow in the pressure fluid connection is influenced by a damping element and a valve is arranged in a bypass in parallel with the damping element, the valve comprising a valve closure surface which is engageable with a valve seating and which is arranged to be displaced off the valve seating so as to open the bypass when the pressure in one of the two working chambers falls below a predetermined value.

2. A hydropneumatic suspension system according to claim 1 in which the damping element comprises a part of the pressure fluid connection which has a restricted cross-sectional area that acts as a throttle.

3. A hydropneumatic suspension system according to claim 1 in which the damping element comprises a valve which has spring-loaded throttling bores.

4. A hydropneumatic suspension system according to claim 1 in which the damping element comprises a variably alterable damping device.

5. A hydropneumatic suspension system according to any one of the preceding claims in which the valve closure surface is exposed to the pressure of the accumulator.

6. A hydropneumatic suspension system according to any one of the preceding claims in which the valve closure surface is provided on an axially displaceable control element of the valve which has at least one surface exposed the pressure in one of the working chambers and at least one other surface exposed to the pressure of the accumulator.

7. A hydropneumatic suspension system according to any one of claims 1 to 5 in which the valve closure surface is provided on a valve closure member connected to an axially displaceable control element which has at least one surface exposed to the pressure of the accumulator.

8. A hydropneumatic suspension according to claim 6 or claim 7 in which the valve control element has a surface exposed to atmospheric pressure.

9. A hydropneumatic suspension according to any one of the preceding claims in which the valve closure surface is biased by a spring into a closed position in which it engages with the valve seating.

10. A hydropneumatic suspension according to any one of the pr ceding claims in which the damping l ment and the valve in th bypass are incorporated within a common com-

ponent.

11. A hydropneumatic suspension system substantially as described herein with reference to Figure 1 of the accompanying drawings.

12. A hydropneumatic suspension system according to claim 11 but which incorporates the modification substantially as described herein with reference to Figure 1a of the accompanying drawings.

13. A hydropneumatic suspension system substantially as described herein with reference to Figure 2 of the accompanying drawings.

14. A hydropneumatic suspension system substantially as described herein with reference to Figure 3 of the accompanying drawings.

15. A hydropneumatic suspension system substantially as described herein with reference to Figure 4 of the accompanying drawings.

16. A hydropneumatic suspension system substantially as described herein with reference to Figure 5 of the accompanying drawings.

17. A hydropneumatic suspension system substantially as described herein with reference to Figure 6 of the accompanying drawings.

18. A hydropneumatic suspension system substantially as described herein with reference to Figure 7 of the accompanying drawings.

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